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PREDICTING SUBSEQUENT MYOPIA IN INITIALLY PILOT-QUALIFIED USAFA CADETS

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Each year a number of previously pilot-qualified USAF Academy cadets become unqualified on the fisual portion of the physical examination and become ineligible for pilot training. This research was directed at determining the ability of a measurable visual characteristic, the dark focus of accommodation, to predict the onset of myopia. Specifically, it was hypothesized that the disparity between the dark focus and the visual far point may be used as an index of the tendency to develop myopia. The cadet population was sampled for measures of the dark focus and, for those cadets who volunteered, the far point data was collected form medical records. Due to circumstances, data collection was dependent upon volunteer participants rather than a planned-for sampling procedure. The data collection was conducted at the end, rather than the beginning, of the academic year. Despite the limitations noted above, there was some evidence to suggest that the hypothesis had merit. To determine the validity of the hypothesis and the suitability of the proposed measure, a longitudinal study should be conducted.

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Predicting Subsequential Myopia In Initially Pilot-Qualified USAFA Cadets

Technical Abstract* (Limit your abstract to 200 words with no classified or proprietary information/data.)

Each year a number of previously pilot-qualified USAF Academy cadets become un-qualified on the visual portion of the physical examination and become ineligible for pilot training. This research was directed at determining the ability of a measurable visual characteristic, the dark focus of accommodation, to predict the onset of myopia. Specifically, it was hypothesized that the disparity between the dark focus and the visual far point may be used as an index of the tendency to develop myopia.

The cadet population was sampled for measures of the dark focus and, for those cadets who volunteered, the far point data was collected from medical records. Due to circumstances, data collection was dependent upon volunteer participants rather than a planned-for sampling procedure. The data collection was conducted at the end, rather than the beginning of the academic year.

Despite the limitations noted above, there was some evidence to suggest that the hypothesis had merit. To determine the validity of the hypothesis and the suitability of the proposed measure, a longitudinal study should be conducted.

Anticipated Benefits/Potential Commercial Applications of the Research or Development

The most immediate benefit of this measure will be savings to the service acad-emy through retention of a higher percentage of cadets who remain pilot-qualified. This same procedure would apply to other rigorous academic programs that suffer from high attrition due to loss of visual acuity. Commercial potential for screening measure for those who might develop myopia would apply to a variety of occupations, e.g., word processors and other visual display terminal users.

List a maximum of 8 Key Words that describe the Project.

Myopia, Visual Performance, Dark Focus, Visual Accommodation, Vision

*Nothing on this page is classified or proprietary information/data

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PREFACE

1.0 OVERVIEW

The research conducted in this effort was directed at determining the ability of a visual factor to predict the onset of myopia in previously pilot-qualified Air Force Academy cadets. It was hypothesized that the dark focus of accommodation (a characteristic focal state assumed by the eye in the absence of patterned visual stimulation) may predict those cadets who will develop myopia over the course of study at the academy. The specific hypothesis to be tested was that the disparity between the dark focus and visual far point was a correlated factor with the onset of myopia. Namely, a near dark focus will tend to result in a myopic trend in the far point.

This research project used the laser optometer to measure the dark focus and relied on existing medical records for far-point data. Due to circumstances beyond control, data collection did not follow the planned schedule. Primary factors were the date of contract award and problems related to access to the cadet population. This changed both the time of data collection (from early in the fall semester to late in the spring semester) and the selection process. Participants were solicited as volunteers and the distribution among the classes was very uneven.

Although the data and timing limited the results of this effort, there is evidence to suggest that the hypothesis has merit. The dark focus remained constant across classes, and the incidence of myopia increased with time in the USAFA. Future research concentrating on longitudinal studies following cadets throughout their career should prove to be the most suitable approach.

2.0 INTRODUCTION

2.1 Background

In order to be qualified for pilot training, U.S. Air Force Academy cadets must meet rigid visual acuity standards. Pilot-qualified cadets are generally mildly hyperopic (farsighted) or emmetropic (normal vision). Although a cadet may have met these standards upon entry to the Academy, he may become disqualified upon graduation due to refractive error. It has been known that refractive changes in vision are likely to occur during late adolescence and early adulthood, the age of a typical college student. During college years, hyperopia tends to diminish and myopia (nearsightedness) tends to increase.

Goodson (1981) reported a significant drop in the number of pilot-qualified cadets graduating from the USAFA due to vision deficiencies. Since the USAFA is mandated to graduate 60% of its cadets for pilot training, it is critically important that the percentage lost to visual factors be reduced to the lowest possible level. Due to several factors, not all entering cadets will graduate from the Academy. Thus, the pilot-qualified class will include only those who are remaining at the Academy and who are emmetropic or hyperopic upon graduation.

A similar trend towards myopia and student attrition has been observed also at other military academies and training programs requiring visual acuity for technical specialties. In an early longitudinal study of ophthalmic records of midshipmen at the U.S. Naval Academy, Hynes (1956) analyzed the visual acuity of several consecutive classes. The midshipmen in this study had to meet visual requirements similar to those of the USAFA cadets to be accepted and to be commissioned as a U.S. Navy ensign or a U.S. Air Force second lieutenant. Living in a controlled academy environment (study, diet, sleep, etc.), refractive changes were attributed to normal biological or physiological changes.

Although emmetropic upon admission, many midshipmen received myopic prescriptions during their freshman year, which were subsequently increased in strength up to graduation. By dividing the data into age groups, Hynes discovered that the younger applicant who is emmetropic or less than +0.50 D hyperopic is more likely to develop some degree of myopia or myopic astigmatism within his next four years. The older applicant was less likely to develop vision defects. Hynes recommended requiring applicants to be greater than +0.50 D in order to reduce the myopic attrition rate.

To protect itself from losing potential pilots, the Air Force needs to develop procedures to ensure that the required number of pilot-qualified cadets will graduate from

the USAFA. Currently, to be pilot-qualified, a cadet must meet certain visual standards. Refractive error cannot be greater than +2.00 D hyperopic or less than 0.0 D (if under 21) or -0.25 D myopic (if over 21), with at most +0.75 D astigmatism. Table 1 lists the visual standards. Other flying classes (pilot waiverable) are also listed, with accompanying visual standards. It should be noted that hyperopia limits exist along with the myopia limits. Among other reasons, this is to ensure that as presbyopia develops at a later age, there is a delayed onset of requiring correction for nearer objects such as flight instruments.

If the potential number of acceptable applicants is insufficient, there may be a requirement to optimize selection within the current constraints. This would require identifying potential myopes at a pre-entry examination. The method would have to do so accurately, reliably, and, for pragmatic reasons, quickly. Reliability implies that the measure is consistent from one measurement instance to another and from one examiner to another, and that it exhibits this measurement stability for a reasonable period of time. The measurement device should also allow for rapid assessment. Currently, the length of time allotted to most physical examinations is extensive and for any measure to be accepted, it must not require much additional time for administration.

An approach is needed that will exclude the minimum while maintaining the required proportion of pilot-qualified graduates. Therefore, a measure must be found that will identify those individuals within the entry group who will become unqualified upon graduation. This measures, in effect, a predisposing factor toward myopia in an ostensibly normal or hyperopic population.

2.1.1 The Dark Focus

A factor with the potential of identifying a myopic tendency is the dark focus. The classic assumption that the observer with "normal" vision has a relaxed state of accommodation at optical infinity has been known to be false in most instances (Leibowitz and Owens, 1975). Evidence suggests that, in the absence of patterned stimuli, observers assume a characteristic intermediate resting position of visual accommodation.

A puzzling and persistent problem has been the anomalous manifestation of inappropriate visual accommodation, i.e., the observer is focused nearer or farther than would be expected. Under low illumination levels, distant stimuli are more difficult to resolve. Called "night myopia" (Leibowitz and Owens, 1975), refractive power of the eye increases for distant objects. Night myopia has been known for at least two centuries, with a report in 1789 by the royal astronomer Lord Maskelyne that his night observation

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TYPE OF EXAMINATION	DISTANT VISION	NEAR VISION	REFRACTIVE
FLYING CLASS I (PILOT)	20/20 Each eye	20/20 Each eye	+2.00 Plano under 21 -0.25 over 21 0.75 Astig.
FLYING CLASS I with WAIVER (PILOT WAIVERABLE)	20/50 Correctable to 20/20 each eye	20/50 Correctable to 20/20 each eye	+2.50 (+3.00 if sph. equiv. does not exceed +2.50 -1.25 in any meridian
FLYING CLASS IA + (SG PILOT WAIVER)	20/100 Correctable to 20/20 each eye	20/20 Each eye	+ no set standard -2.00 sph. equiv.

+ This category is available for USAFA Cadet classes 82-86 only.

TABLE 1.   USAFA Visual Standards

was facilitated by the use of a negative lens. Another type of myopia, "empty field myopia" or "space myopia," discussed in detail by Whiteside (1957), has particular reference to high altitude flight, such as air-to-air search. The eye is focusing at relatively close distances, rather than to distant objects. Empty-field myopia occurs when viewing an unstructured field (no contours), such as the clear sky, a snow storm, or fog. A third myopia, "instrument myopia," results in unnecessary increases in accommodation when looking at targets of high contrast and rich detail through instruments such as microscopes (Hennessy, 1975).

Leibowitz and Owens (1975) investigated the relationship between the anomalous myopias and the dark focus of the eye. Using a laser optometer, they measured the accommodation of 124 subjects in total darkness, finding a mean dark focus of 1.7 D (59 cm). The three anomalous myopias were then experimentally simulated. Their results supported the dark focus hypothesis, i.e., the eyes assumed a resting state of accommodation, rather than focusing at optical infinity.

2.1.2 Stability of the Dark Focus

In using the dark focus for selection, prediction, etc., it is important to consider the reliability of the measure. The temporal stability of the resting state, both "trait" stability and "state" stability, must be defined. The former is indicative of a long-term invariance in the measure – something characteristic of the person's inherent make-up. The latter is indicative of temporary fluctuations about such a trait level. Evidence of dark focus shifts concomitant with mood is limited. Westheimer (1957) found, during an investigation of the resting position in empty fields, that when subjects were angered by insults from the experimenter, a rise in accommodation lasting several minutes was observed.

These reports do not indicate that the dark focus is unreliable. In fact, similar results are often found in the time-honored acuity measures. In terms of the potential for pilot selection/classification, a cautionary note on the lability of the dark focus would be in order. Just as those with marginal acuity fail to meet visual acuity standards under stressful situations, it would be expected that a number of individuals with a dark focus measure near a cut-off point might fail to prove acceptable on one measurement instance, but would "pass" on a second. Whether individuals with this type of lability should be acceptable or not is an empirical question.

As for trait stability, Miller (1978) measured the dark focus in 21 subjects over two to three weeks and found it "stable." Owens and Higgins (1979) reported the stability of

the dark focus for five subjects over a one-year period. They noted individual differences in the magnitude and pattern of variability of the dark focus, but the subjects oscillated about a stable mean dark focus over the measurement period. Mershon and Amerson (1980) have shown that the change in dark focus can be less than plus or minus 0.3 D.

2.1.3 Measuring the Dark Focus

Numerous methods and instruments have been proposed for measuring the refractive state of the eye. In clinical practice, retinoscopy is one common method and has been adapted to the measurement of the dark focus. The instrument requires considerable training and practice to use. A number of alternative devices have been developed to measure accommodation objectively. Some of these devices are quite complex and expensive (e.g., the SRI infrared optometer and eye tracker; Crane and Steele, 1978). Although the more complex devices may provide continuous readout of accommodation, for purposes of dark focus measurement, a momentary reading is sufficient. The laser optometer (Leibowitz and Hennessy, 1975) is an inexpensive alternative that is relatively easy to construct and use. By using the Badal principle, a compact, portable device may be constructed which provides an objective measure of the true refractive state. The optical image viewed is a speckle pattern resulting from divergence and reflectance of the laser light from a moving surface. Visual accommodation is evaluated by superimposing the speckle pattern into the field of view of the observer, who reports the direction (or lack) of speckle pattern movement. The major advantage of this device for dark focus measure is that the laser speckle pattern does not serve as an accommodative cue. Therefore, unconfounded measures of the dark focus are possible. The device requires modest training for users, is relatively unobtrusive, and has a historical precedent for its use.

The optometer design chosen for use in this research is the field laser optometer (FLO), designed by Hennessy and Richter (1979). A FLO was built for USAFSAM/NG. It is a ruggedized design to ensure constant component alignment, is compact in size, has motorized adjustment of the optical path length, and has the potential to provide a light-free viewing environment between measures. The laser optometer had been approved previously for human use (see Appendix A).

2.2 Hypothesis

Since individuals vary in the precise position of their dark focus and the dark focus appears predictive of certain aspects of visual functioning, it is likely that the dark focus

may also be a determinant of future myopia in a normal or low hyperopic population. The dark focus may interact with the far point to result in an inward shift in the far point. The amount of the shift may be related to the disparity between the dark focus and far point. A large disparity may have a greater potential to induce a shift, and the shift may be greater when it occurs.

The rationale for this hypothesis involves the preferred focal state that the dark focus appears to represent. The dark focus is by definition manifested in the absence of visual stimulation, but it is also found when targets of varying accommodative stimulus value are presented. Benel (1980) illustrated the persistent effects of the dark focus on accommodation. Even with high-contrast targets, there was the persistent lead and lag of accommodation (a phenomenon not unknown in clinical optometric examinations). This preferred state of accommodation may develop sufficient inertia to draw the far point (and near point) toward its position.

If this is true, then a selection process may be developed for entry into the USAFA. The process could take the form of modified multiple cut-offs for acuity, refraction, and dark focus. The process would be "modified," because there are likely to be significant correlations among measures, and acuity and refraction values are essential factors. The dark focus is likely to be a relative measure with the far point as reference, but it may be that a true multiple cut-off approach using absolute dark focus values would work. The exact mechanism to implement such an approach has been the purpose of this research.

2.3 Technical Objectives

There were three main objectives within Phase I. They were:

- o Develop a rapid screening measure of the dark focus of accommodation suitable for the target population
- o Establish the relationship between the dark focus and far point for the target population
- o Detect trends in onset of myopia in relation to the disparity between dark focus and far point.

3.0 APPROACH

An experimental approach was utilized to develop a measure of visual testing that would enable identifying cadets with a myopic tendency. The research plan included a sample of USAFA cadets who were tested for their dark focus measures on both eyes. Dark focus was measured by a laser optometer. In addition, far-point visual data were obtained from cadet medical records. The relationship between dark focus and far-point focus was investigated.

3.1 Subject Selection

U.S. Air Force Academy cadet volunteers were recruited to be subjects. Participation was solicited by classroom instructors and through direct contact as they passed by the experimental room. Detailed descriptive data on the selected cadets is contained in a subsequent section.

To participate, a cadet had to be pilot qualified upon entry to the Academy. All of the cadets except one fit this requirement. It was not discovered initially that this subject was not pilot qualified when he entered the Academy. Only the classes of 1985 and 1986 also had a more recent qualification status. Eight cadets had remained pilot qualified, eight had became pilot waiverable, one was commissionable (the subject just mentioned), and three were missing a status. The data of the subject who was commissionable were dropped from the statistical analyses. Of the 91 cadets, 16 wore glasses; ten of the 16 wore glasses for distance and six wore them for reading. Two cadets wore contact lenses.

3.2 Apparatus

The laboratory apparatus used to measure dark focus was a field laser optometer (FLO), designed by Hennessy and Richter (1979). It measures a range of accommodation between +9 D to -3 D. The FLO consists of two units, the optometer head and the control box.

The optometer head contains a red helium-neon laser which emits a coherent beam. The beam passes first through a shutter and is then expanded, reflected by mirrors, and filtered. The beam is next reflected off a slowly rotating drum and then it passes through a set of relay lenses, a fixed prism, a moveable prism, and a badal lens before reaching the subject's eye. Figure 1 is a schematic representation of the field laser optometer
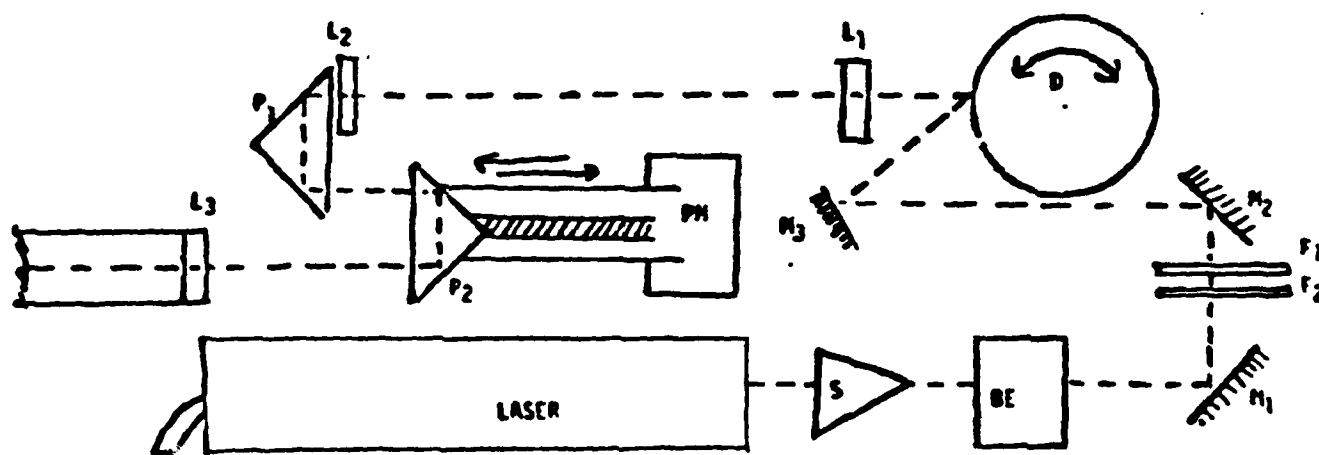
LASER - 2.0 mw He-Ne laser
M₁,M₂,M₃ - Front surface mirrors
S - Shutter
D - Rotating drum
PM - Prism traverse motor
L₃ - Badal lens

BE - Beam Expander
F₁,F₂ - Light control filters
L₁,L₂ - Relay lenses
P₁ - fixed Porro prism
P₂ - moveable Porro prism

FIGURE 1

Schematic Representation of Field Laser Optometer (FLO) Head

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head. The beam appears to the subject as a red circle, the elements of which may appear either moving or stationary. Because the raw laser beam is not exposed but is a diffuse reflection, the laser has been evaluated to be eye safe by the AMRL Human Engineering Branch of the USAF Medical Center.

The optometer head measures 24 inches high by 13 inches wide by 6.5 inches deep. On the front is an adjustable chin rest with holders for use with the right or left eye, allowing the subject to look into a box containing the image. On the side of the optometer head is a scale and a pointer which indicates the position of the moveable prism. These scale values are used to determine accommodation in diopters. The calibration chart is shown in Figure 2.

The control box, which measures 9.5 inches high by 13 inches wide by 9 inches deep, controls the shutter, the moveable prism, the drum, and the laser. Each of these components is separately controlled by its own subunit:

- o Shutter Control – The shutter can be opened or closed for a specified time interval or it can be set to remain open.

- o Prism Positioning Control – The moveable prism changes the appearance of the speckle pattern. Its motor drive controls speed, speed range, and direction of motion.

- o Drum Drive Control – The drum generates the reflected speckle pattern. Its motor controls drum rotation speed and rotation direction.

- o Laser Power Control – The laser is activated by an on/off switch.

3.3 Procedure

3.3.1 Dark Focus Measure

3.3.1.1 Familiarization — Each participant received a briefing statement on the nature of the experiment and the apparatus prior to the experimental session. Copies of these statements were either handed out by instructors in class or picked up from a table outside the experimental room upon scheduling a time convenient to the cadet.

INSTRUCTIONS

At the beginning of the experimental session, the experimenter introduced herself and asked the cadet if he or she had read the briefing statement. Some cadets had received the statement but had not read it. Others had not picked up the statement from
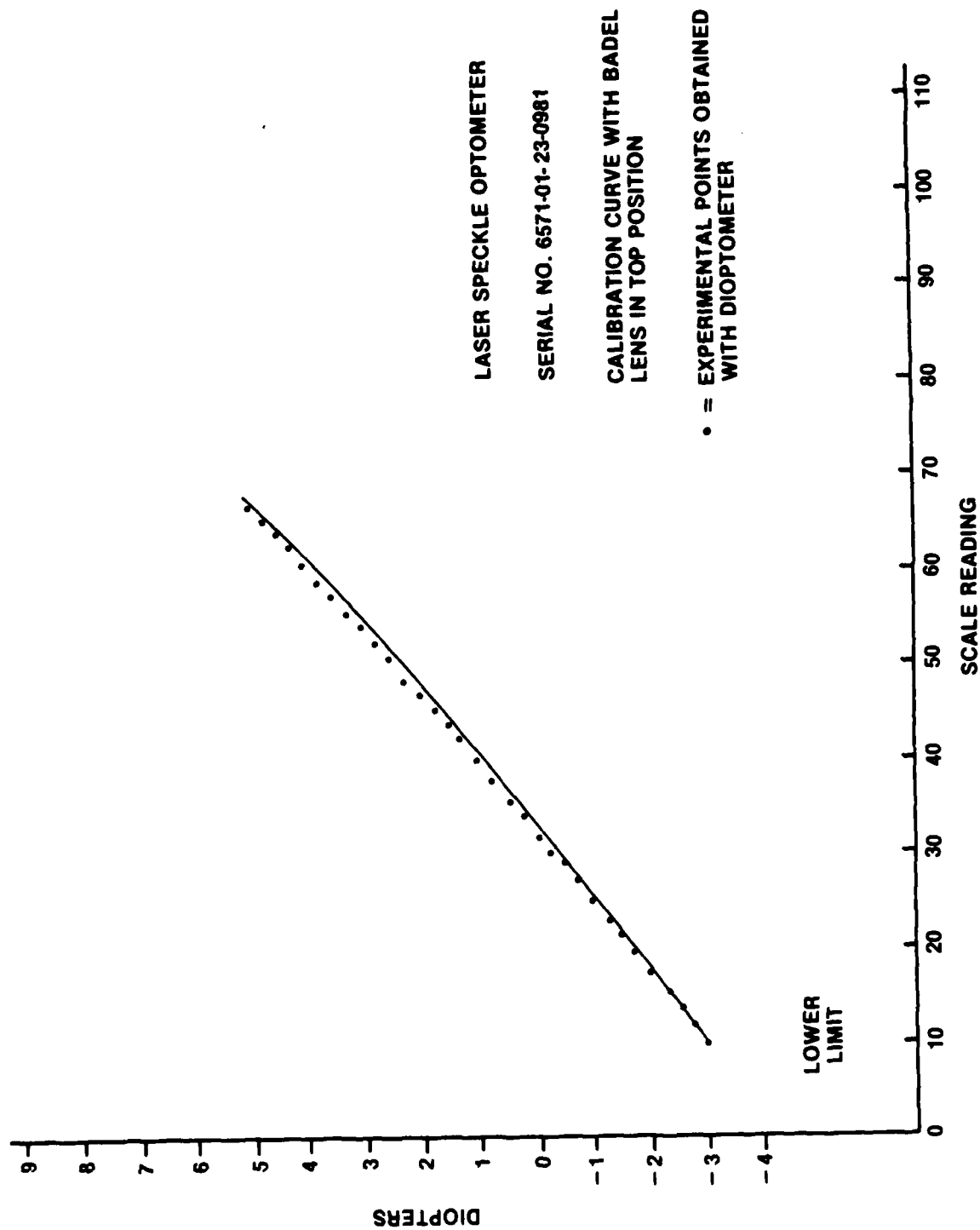
LASER SPECKLE OPTOMETER

SERIAL NO. 6571-01-23-0981

CALIBRATION CURVE WITH BADEL
LENS IN TOP POSITION

• = EXPERIMENTAL POINTS OBTAINED
WITH DIOPTOMETER

FIGURE 2.
LASER OPTOMETER CALIBRATION CURVE

SCALE READING

DIOPTERS

LOWER
LIMIT

11

the table. An informed consent *form was also signed by the subject and the experimenter* (see Appendix B). For all subjects, the purposes of the experiment was explained:

1. To develop a visual test that would assist the USAFA in predicting whether or not a potential cadet or a current cadet has a tendency towards myopia or near-sightedness.

2. To be able to screen applicants and cadets to ensure that the Academy will be able to graduate a certain percentage of cadets to be pilot qualified. This screening will enable the applicant and/or cadet who has a myopic tendency to be identified as a candidate for ameliorative measures (yet to be developed) or consider his commitment to the the USAFA and the Air Force, especially if his or her aim in life is to be a pilot.

Next, the experimenter explained the measure of dark focus and how it relates to flying and nearsightedness (empty field, blue sky, fog; where there is an absence of patterned stimuli in the field of view). The cadet was told that the dark focus measure would be analyzed in relation to his or her far-point (distant) focus data, which were to be taken from medical records contained in the cadet clinic.

The cadet was introduced to the laser optometer. He or she was told that the optometer contains a laser that is viewed indirectly, due to the fact that it is diffused, reflected, split, and filtered before it reaches the eye. The image to be viewed was explained to be a red circle containing a pattern with speckles that appear to be moving UP or DOWN, or appear to be STOPPED. The point at which the pattern stops moving is where the cadet dark focuses. Each cadet was given a brief overview of the data collection procedure.

PHYSICAL CONTACT WITH THE LASER OPTOMETER

After the instruction phase, the lights were turned off and the optometer was turned on. With the shutter open, the cadet was given the opportunity to adjust the chin rest to allow for a clear view of the image. The right eye was measured first, with the left eye closed, followed by the left eye measurement.

Once the chin rest was adjusted and the view of the image was optimized, the cadet was asked to observe the direction of movement within the red circle. The red circle was positioned in the maximum UP position. The control settings were the following:

o Shutter — OPEN

o Prism speed — 15

o Prism drive switch — BRAKE

o Speed range switch — LO

o Drum drive switch — FWD

o Drum drive speed — 50 (0.3 RPM)

If the cadet responded correctly that the image appeared to be moving UP, he or she was told that the image would be seen in continuous motion, changing from UP to STOPPED to DOWN. The prism drive switch was changed to FWD. The cadet called out the motion viewed. This served as a definition of the movement patterns.

3.3.1.2 Data Collection — When the cadet understood and could identify UP, STOPPED, and DOWN, the data collection phase began. The cadet was asked to close his or her eyes when the experimenter said "CLOSE," and to open only the eye being tested when the experimenter said "OPEN" (right eye first, then later the left). At that point, the shutter-actuate switch on the shutter timer control was pushed, and the stimulus was presented for one second. The cadet responded with the direction of motion.

A bracketing technique was used to gradually narrow down the range of movement by successive exposures and responses to the stimulus. Exposure began at the maximum UP position. The prism speed was set on 40 to allow for faster change of direction. The prism drive switch was successively positioned FWD (down) and REV (up) after each exposure until the cadet had responded that the movement had stopped. In some cases, exposure may have been repeated because the cadet may have moved, thus losing visual points of reference. When that occurred, the prism drive switch was activated toward the end of the scale closest to the last exposure setting. The shutter was reopened until the cadet readjusted himself or the chin rest to obtain a clear view of the stimulus.

When the cadet responded "STOPPED," the value on the scale on the side of the optometer was recorded, while allowing a brief rest. The procedure was repeated three times for the right eye. After the third trial, the prism drive switch was set on REV, returning to the maximum UP position. The chin rest was transferred from the left holder (right eye position) to the right holder (left eye position). The shutter was reopened, and the cadet adjusted his view. The bracketing technique was repeated for the left eye three times. The mean was calculated for both the right and left eye measures. These values were later transformed into diopters of dark focus.

3.3.1.3 Debriefing — The debriefing session followed data collection when the lights were turned back on. The cadet was told approximately where he or she dark-focuses in feet. The point was made that when flying in an empty field or in the dark, eyes assume the resting stage of dark focus. In that instance, the cadet was told to be aware of dark focus, and to push himself or herself to use his or her far-point focusing

ability. This is especially true if he or she must do air-to-air target search and detection. In order to switch focusing modes, techniques such as actively scanning cockpit instruments, the horizon, the clouds, and the frame of the canopy, etc., were suggested.

The cadet was thanked for participating and was given a debriefing statement which summarized the experiment and its purpose. Any questions posed by the cadet were answered.

3.3.2 Refraction Measurement

The medical records of each cadet tested on the laser optometer were accessed from the cadet clinic. Within each record, far-point visual data from each cadet were obtained. Although two types of visual acuity data existed — manifest refraction and cycloplegic refraction — it was decided to use the cycloplegic measure. Visual acuity is measured by first inserting into one's eyes drops of cyclopentalate (1%), which paralyzes the ability of the lens to accommodate. Absolute accommodation (true refractive power of the lens) can thus be measured. Cycloplegic refraction differs from manifest refraction in that manifest refraction is more variable. Nearsightedness can be artificially induced by environmental factors, such as stress and eyestrain.

All visual data included a spherical measure of refractive power. In addition, several cadets also had a cylindrical measure representing an astigmatism. These two values were added together to obtain a consistent value across all cadets of their refractive power. For example, a cadet with +0.75 D spherical and a -0.50 cylindrical (astigmatism) resulted in a refractive power of +0.25 D, his worst possible refractive power.

Both the latest and the earliest cycloplegia tests (if available) were recorded, in addition to in-between tests (for eight subjects). The only and latest cycloplegic refractions for the classes of 1988 and 1987 were done prior to acceptance to the Academy on their Department of Defense Medical Evaluation Review Board (DODMERB) physical examination. The DODMERB cycloplegia requirement started with the class of 1987. The classes of 1986 and 1985 had their earliest cycloplegic refraction done during their fourth class physical in their freshman year. A subsequent latest cycloplegic refraction was done during their graduation physical in their junior year.

4.0 RESULTS

Data were collected from the 91 participants in accordance with the plan and procedure described in the previous section. Due to the selection procedure, the distribution of participants was not as originally anticipated. The implication of the skewed distribution will be discussed in a following section, but the dependency of the data upon relatively equal numbers of participants from all classes will become obvious within the results.

4.1 Descriptive Statistics

In the original plan, data were to be collected from cohorts of USAF Academy cadets who were pilot-qualified upon entry to the academy. This implied that only those who had been qualified to become pilots upon entry would be selected for participation and that the selection would be made by the academy for the purposes of this research. Furthermore, the sample of first-year cadets was anticipated to contain only pilot-qualified cadets, while the samples from the upper classes would be likely to contain increasingly more cadets who were no longer qualified. This assumption was based on the date that was assumed for data collection in the original plan (November 1984) and the coordination of the sampling approach with personnel cognizant of the loss rate that had been experienced at the academy. This would have led to an optimized data collection procedure.

Through a series of conversations with Academy personnel, it was determined that participation on a voluntary basis would be solicited from the cadets. Because the sample that was available was based on voluntary participation rather than a selection procedure, the actual participants differ significantly from the population sample that had been anticipated. As was mentioned above, the most significant departure from the sampling approach was the representation by class. Within each class, the availability and comparability of data was not as consistent for the visual examination data as had been anticipated.

Figure 3 illustrates the overrepresentation of the class of 1987 in the sample of available cadet volunteers. Figure 4 illustrates the number of cadets of each age within the sample. Obviously, the majority are either 18 or 19 years old, consistent with the overrepresentation of the class of 1987. Table 2 represents the relationship between class and age for the sample.
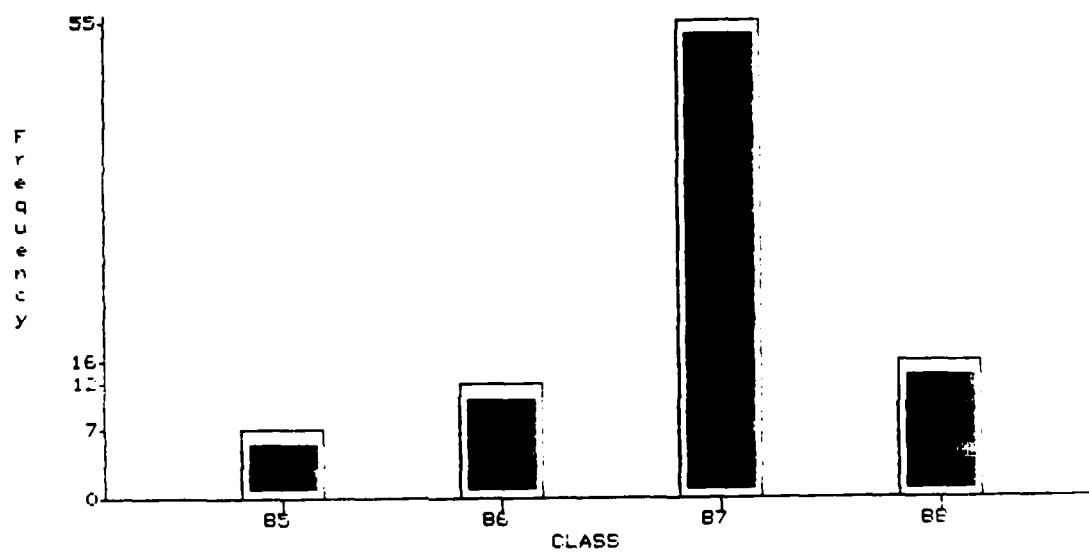
FIGURE 3

Class Distribution

Frequency

34

25

16

8
5
2
0
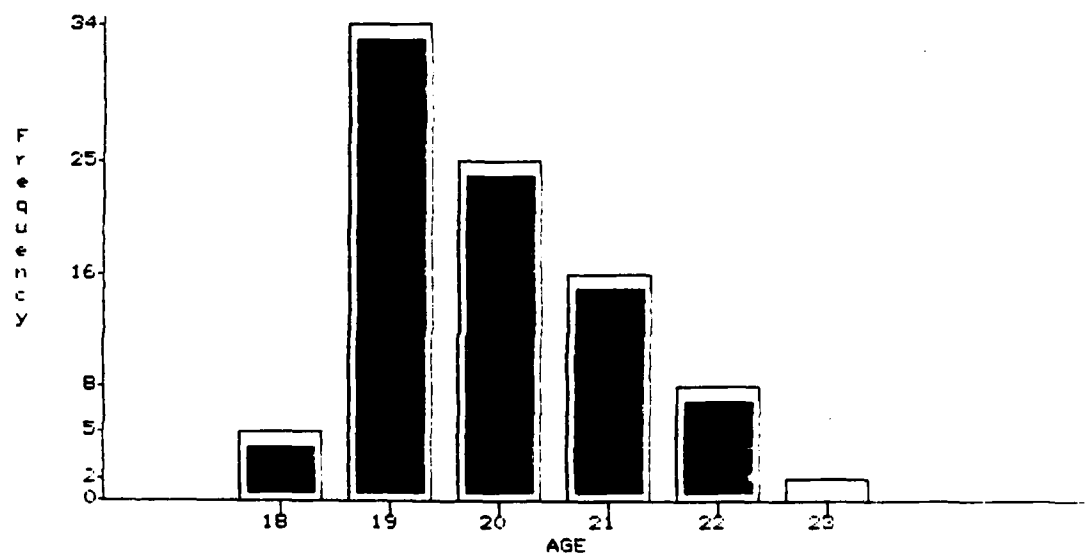
18   19   20   21   22   23
AGE

FIGURE 4

Age Distribution

17

Tabulation of CLASS (rows) by AGE (columns)
(Frequency/Row percent/Column percent)

	18	19	20	21	22	23	
85	0 0.00 0.00	0 0.00 0.00	0 0.00 0.00	2 28.57 12.50	3 42.86 37.50	2 28.57 100.00	7 7.78
86	0 0.00 0.00	0 0.00 0.00	1 8.33 4.00	9 75.00 56.25	2 16.67 25.00	0 0.00 0.00	12 13.33
87	1 1.82 20.00	24 43.64 70.59	23 41.82 92.00	5 9.09 31.25	2 3.64 25.00	0 0.00 0.00	55 61.11
88	4 25.00 80.00	10 62.50 29.41	1 6.25 4.00	0 0.00 0.00	1 6.25 12.50	0 0.00 0.00	16 17.78
	5 5.56	34 37.78	25 27.78	16 17.78	8 8.89	2 2.22	90

TABLE 2

Relationship Between Sample Class and Age

Although the sample sizes present some inherent limitations, the percentage of cadets wearing corrective lens increases within each class (with the exception of the class of 1985). The percentages within each class, beginning with the class of 1988, were 0, 17, 46, and 15. This is generally consistent with the findings of others, as discussed in the introduction.

The dark focus data for the right and left eyes were consistent with that collected by Leibowitz and Owens (1975). As can be seen in Figures 5 and 6, the distributions of the dark focus are approximately normal, given the inherent bias toward hyperopia within this sample in comparison to the population of college students measured by Leibowitz and Owens. The means for this sample also: compare favorably 1.86 and 2.34 D for the right and left eye, respectively, with a standard deviation of 1.25 D for both. Leibowitz and Owen had reported a mean of 1.71 D.

The relationship between age and the dark focus, although not entirely consistent, tends to reflect an increase in the measured dark focus through the ages sampled in this study. As can be seen in Table 3, the data for the right eye show a regular increase, with the exception of the 21-year-olds. The data for the left eye are similar, also showing a reversal of the trend at age 21. For the 21-year-olds, 38% wear glasses. This percentage is twice that of glass wearers in the total population.

The data from the most recent cycloplegic examination are depicted in Figures 7 and 8. The majority of the cadets have a result in the range encompassed by 0.0 to +0.75 D hyperopic (approximately 76 and 74% for the right and left eye respectively). This result is consistent with the selection process for cadets on visual parameters. In fact, at entry the percentages had been higher (e.g., all 16 of the class of 1988 were within that range).

4.2 Predictive Statistics

The relationship between the dark focus of the right and left eyes of a group of subjects is generally positive, although differences between the measured values are common. Similarly, the refractive indices between eyes generally correlate highly, although the values are frequently not identical. Table 4 includes the correlation matrix among the visual measures. Within measurement type (dark focus or cycloplegic exam), there is a high degree of correspondence. There is no apparent relationship between the dark focus and the cycloplegic examination data, with the exception of a weak (non-reliable) negative correlation. The negativity reflects the signing conventions used for

19
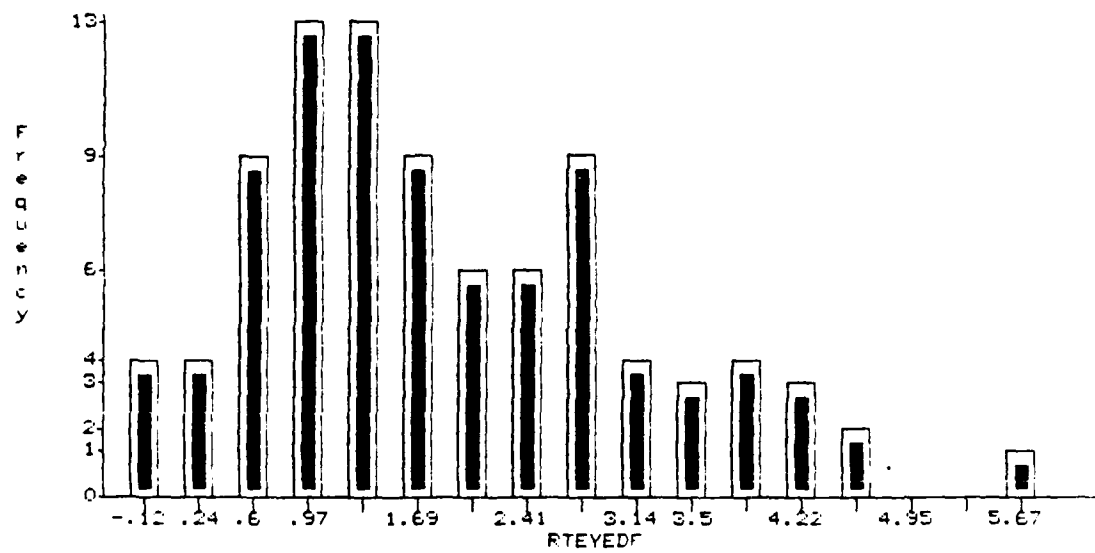
FIGURE 5

Right Eye Dark Focus Distribution
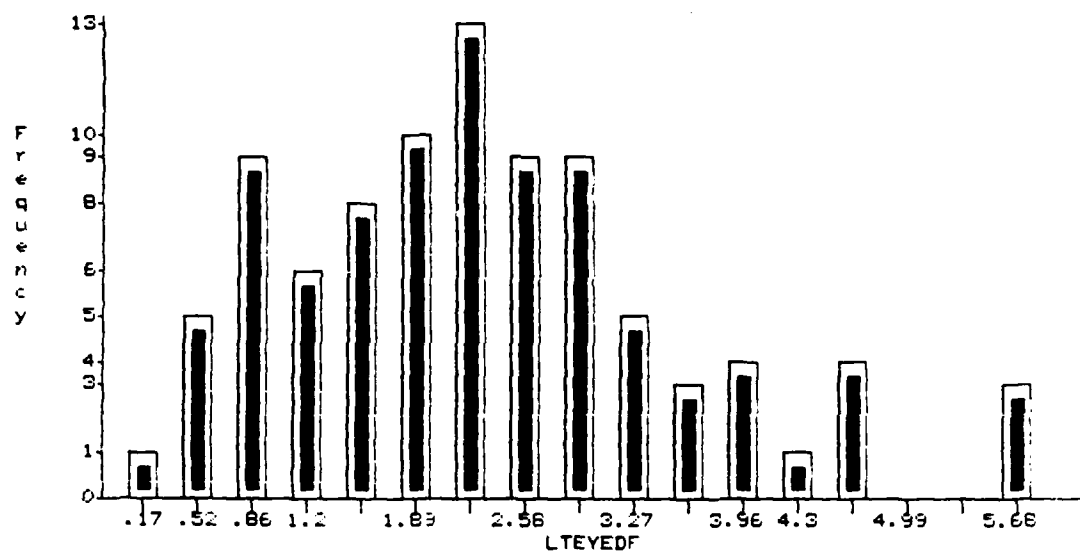
FIGURE 6

Left Eye Dark Focus Distribution

21

AGE TRENDS IN THE DARK FOCUS

AGE	18	19	20	21	22	23
RIGHT EYE DARK FOCUS	1.52	1.78	1.84	1.67	2.42	3.58
LEFT EYE DARK FOCUS	2.14	2.33	2.41	1.89	3.18	2.42
N	5	34	25	16	8	2

TABLE 3

Age Trends in Dark Focus

FIGURE 7

Right Eye Latest Cycloplegia Distribution

FIGURE 8

Left Eye Latest Cycloplegia Distribution

Correlation Matrix

The P-values shown are 2 tailed values.

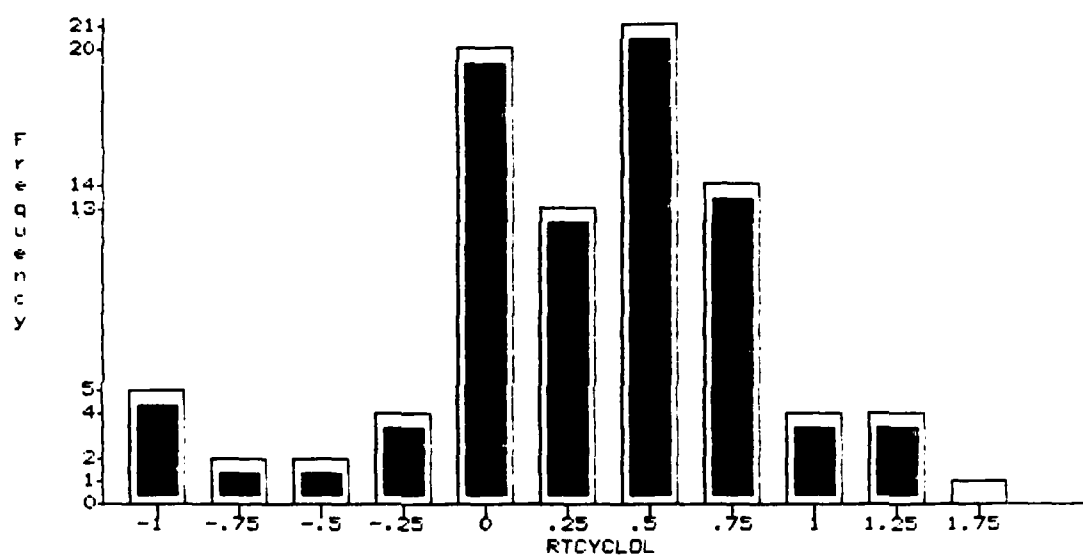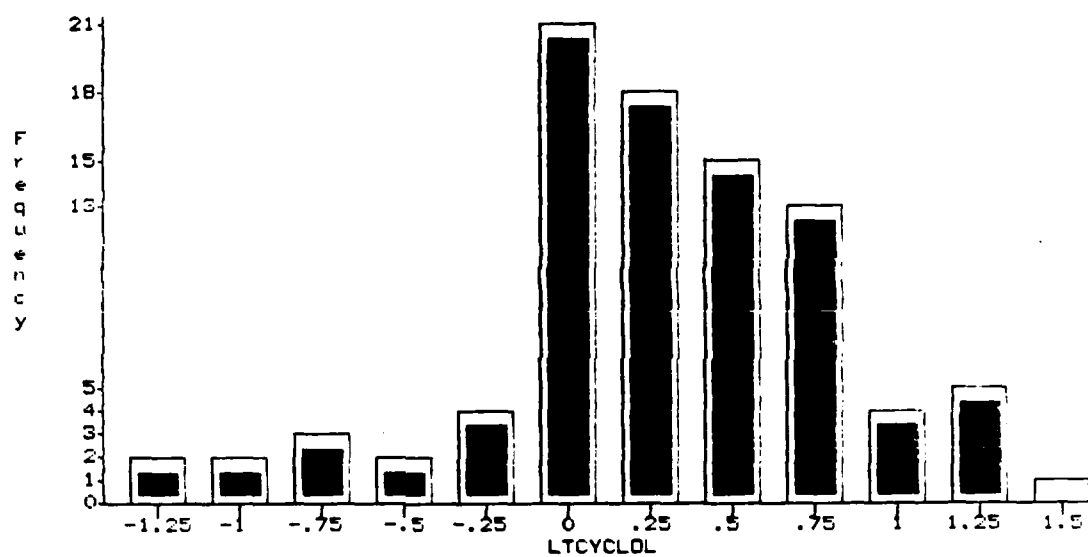|	RTEYEDF	LTEYEDF	RTCYCLOL	RTCYCLOE	LTCYCLOL	LTCYCLOE
RTEYEDF	1.0000	0.6924	-0.1490	-0.1547	-0.1492	0.0709
	0.0000	0.0000	0.1611	0.2260	0.1605	0.5806
	(90)	(90)	(90)	(63)	(90)	(63)
LTEYEDF	0.6924	1.0000	-0.0755	-0.1283	-0.1015	0.0960
	0.0000	0.0000	0.4796	0.3162	0.3413	0.4542
	(90)	(90)	(90)	(63)	(90)	(63)
RTCYCLOL	-0.1490	-0.0755	1.0000	0.7120	0.9269	0.6915
	0.1611	0.4796	0.0000	0.0000	0.0000	0.0000
	(90)	(90)	(90)	(63)	(90)	(63)
RTCYCLOE	-0.1547	-0.1283	0.7120	1.0000	0.6752	0.8378
	0.2260	0.3162	0.0000	0.0000	0.0000	0.0000
	(63)	(63)	(63)	(63)	(63)	(63)
LTCYCLOL	-0.1492	-0.1015	0.9269	0.6752	1.0000	0.6517
	0.1605	0.3413	0.0000	0.0000	0.0000	0.0000
	(90)	(90)	(90)	(63)	(90)	(63)
LTCYCLOE	0.0709	0.0960	0.6915	0.8378	0.6517	1.0000
	0.5806	0.4542	0.0000	0.0000	0.0000	0.0000
	(63)	(63)	(63)	(63)	(63)	(63)

TABLE 4

Visual Measures Correlation Matrix

25

the two measures, but the lack of reliability seems to indicate that the two measures are predominately measures of different underlying phenomena.

Figure 9 depicts the relationship between the right- and left-eye dark focus. Similarly, Figure 10 represents the relationship between the most recent right and left cycloplegic examination data. These scatterplots illustrate the strength of the correlation between visual measures of an individual's eyes, but — as was noted above — very little, if any, relationship exists between these variables and the others available within this study. There is a weak (r=.17, d.f.=88) relationship between age and the dark focus for the right eye, but it is not reliable (p=.11), and there is no similar relationship for age and the left-eye dark focus.

Despite the strong positive correlation between the dark focus for the right and left eye, the difference between them (1.86 vs 2.34) is reliable (p<.01). The relationships among the cycloplegic data indicate that there are no reliable differences either for the left vs right eye or for time of examination within an eye. Examination of the data indicated that the differences were predominantly among the younger (age or class) participants. Above age 21 there were no longer any reliable differences.

When the differences between classes for the dependent variables are analyzed, only the left-eye dark focus appears to reflect anything approaching a reliable difference. Between the classes of 1985 and 1986, there is a 1.2 D mean difference which approaches reliability (t=1.96, d.f.=17, .05<p<.10). Similarly, between the classes of 1986 and 1987 there is a 0.9 D mean difference (t=2.68, d.f.=65, p<.05). The practical significance of these observed difference and their actual reliability are somewhat suspect, given the sampling limitations and the number of statistical tests performed on the data.

Simonelli (1983) reported a measure which he referred to as the relative dark focus. This was calculated by taking the measured dark focus and subtracting the far point. This procedure was developed to "factor out" the effect of ametropias from the dark focus. Employing the same procedure to the data collected in the present study, the calculated relative dark focuses were 1.57 and 2.07 D for right and left eyes, respectively. These relative dark focuses were then correlated with the change in cycloplegic data for those participants who had been measured twice. The correlation matrix for data on both eyes on the two measures is contained in Table 5. A modest increase in the correlation between the right and left dark focus is indicated, and the correlation between the changes in the right and left eye is quite high. There was a tendency for the amount of change to relate to the dark focus. This tendency was reliable for the left eye correlation.
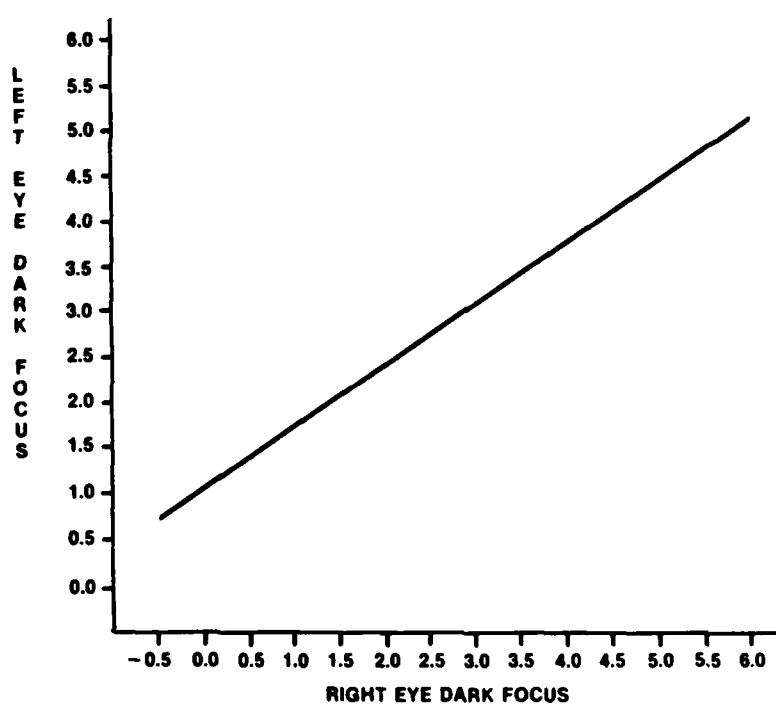
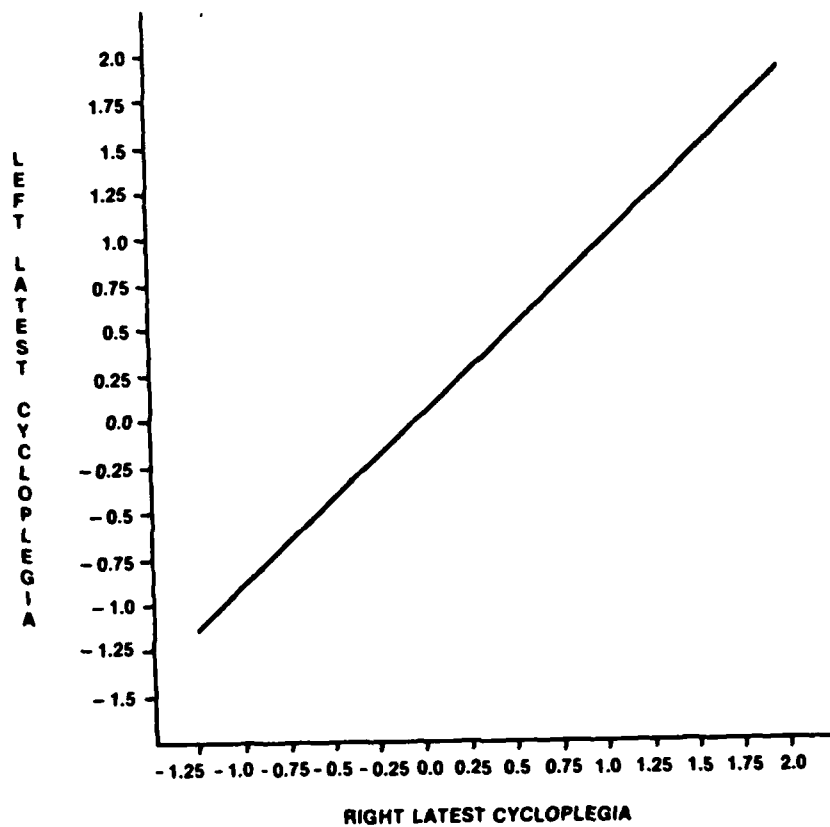**FIGURE 9**

Right by Left Eye Dark Focus

FIGURE 10

Right by Left Eye Latest Cycloplegia

Correlation Matrix

All correlations have 61 degrees of freedom.
The P-values show are 2 tailed values.

	RTRELDF	LTRELDF	RTCYCHG	LTCYCHG
RTRELDF	1.0000	0.7575	-0.1813	-0.3607
	0.0000	0.0000	0.1549	0.0037
LTRELDF	0.7575	1.0000	-0.1616	-0.4396
	0.0000	0.0000	0.2059	0.0003
RTCYCHG	-0.1813	-0.1616	1.0000	0.6897
	0.1549	0.2059	0.0000	0.0000
LTCYCHG	-0.3607	-0.4396	0.6897	1.0000
	0.0037	0.0003	0.0000	0.0000

TABLE 5

Relative Dark Focus by Cycloplegia Change Correlation Matrix

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5.0 DISCUSSION

The primary purpose of the research conducted in this study was to determine the potential for a visual measure (the dark focus) in prediction of subsequent myopia for Air Force Academy cadets. The results of this research do not support unrequivocably the hypothesis that the relationship between the dark focus and the current visual functioning can be used to predict the onset of myopia. Nevertheless, the relationship between the dark focus and the amount of change in refractive power, from entry through the most current examination, indicates that the dark focus bears potential for further research.

The strength of the relationship between the dark focus and the onset of myopia is indeterminate at this point. The primary factor in the weakness of the data was the inability to collect the required data from the samples of the population as originally intended. The limitations of the voluntary sample are evident in the unequal sample sizes among the classes. In addition, the timing of data collection was not optimal. A problem in the underlying data is the variety of timings for the cycloplegic examinations and the apparent inconsistency in the method of collection.

In the original design, data were to have been collected from randomly selected samples of equal size from each of the four classes. The samples were to have been drawn from those who had been pilot-qualified at entry to the Academy. It was expected that the proportion of those remaining pilot qualified would diminish in each class over time and that a variety of visual measures would be changed. Although this sampling approach presented several problems for resolution of the hypothesis that had been proposed, this approach might have allowed differences that did exist based on the dark focus to emerge. As it was, the number of sophomores was twice the sample suggested under the revised data collection approach, and no other class approached the number suggested. Sample sizes of 24 per class were planned for in the revised approach.

The disproportionate number of sophomores may have been related to decisions that were to be made by members of that class in regard to their future. Those beyond that class had relatively less interest, because they had already made their decisions, and those in the freshman class had not had to confront the issue. A large number of sophomores volunteered after being contacted by the experimenter. Interest in knowing their visual capability was a predominant factor in their participation.

Although the dark focus data compared favorably with that of other research, the actual values for the dark focus were somewhat higher than would be expected for the

highly select population that had been measured. All means were calculated based on dark focus readings without glasses. Most cadets who wore glasses did not have them available for data collection. This would tend to bias the data toward a more myopic dark focus than that which had been reported by others (e.g., Leibowitz and Owens, 1975). The small number of cadets (16) who wore glasses and the generally low levels of myopia would mitigate the effect. Thus, the sample of cadets would have a very similar dark focus distribution to that which has been reported previously.

The visual examination data for the cadets are not as crisply defined as the dark focus data. Cycloplegic examinations were not administered to all cadets at identical times in their careers. For some cadets, Department of Defense Medical Evaluation Review Board Tests are now required for classes beginning with the class of 1987. This is performed prior to entrance. For the classes of 1985 and 1986, cycloplegic examinations were not required, and their initial cycloplegic examinations were administered during their freshman year. Additional examinations may be administered if changes are noted or on schedule (e.g., the graduate physical examination is given during the junior year). The initial examinations for cadets may have been done by a variety of personnel under a variety of circumstances, thereby tending to increase the variability in the data.

In addition to the limiting factors noted above, the timing of data collection was less than optimal. Data collection was anticipated for early in the academic year, but actually occurred immediately prior to final examinations for the spring semester. A pure dark focus measure would have been more likely to be gathered prior to the start of rigorous academic efforts. Data collection prior to final examinations is likely to reflect both fatigue and anxiety, which are often manifested in a tendency toward a more myopic dark focus.

If the hypothesized relationship between the dark focus and the onset of myopia were to be supported more fully, the disparity between the dark focus and the far point would be seen to diminish over time, with the far point approaching the dark focus. Based on the limited sample collected and the problems warrant in the data, no firm support is available. Inspection of the raw data for this sample reveals that distance vision becomes worse for a number of cadets, supporting the records cited by Goodson (1981). The dark focus remains similar from the class of 1988 through the class of 1985, supporting its potential as a predictor of the onset of myopia.

6.0 REFERENCES

Benel, R. A. (1980). A functional metric for the description of visual stimuli. Proceedings of the 7th Psyclology in the DOD Symposium. USAF Academy, Colorado Springs, CO, April 16-18.

Crane & Steele (1978). Accurate three dimensional eye tracks. Applied Optics, 17, 691-705.

Hennessy, R. T. (1975). Instrument myopia. Journal of the Optical Society of America, 65, 1114-1120.

Hennessy, R. T., & Richter, D. F. (1979). Technical manual: Field laser optometer (FLO). Camirillo, CA: Authors.

Hynes, E. A. (1956). Refractive changes in normal young men. A. M. A. Archives of Ophthalmology, 56, 761-767.

Leibowitz, H. W., & Hennessy, R. T. (1975). The laser optometer and some implications for behavioral research. American Psychologist, 30, 349-352.

Leibowitz, H. W., & Owens, D. A. (1975). Anomalous myopias and the intermediate dark focus of accommodation. Science, 189, 646-648.

Leibowitz, H. W., & Owens, D. A. (1978). New evidence for the intermediate dark focus of relaxed accommodation. Documenta Ophthalmologica, 46, 133-147.

Mershon, D., & Amerson, T. L., Jr. (1980). Stability of measures of the dark focus of accommodation. Investigative Ophthalmology and Visual Science, 19, 217-221.

Miller, R. J. (1978). Mood changes and the dark focus of accommodation. Perception & Psychophysics, 24(5), 437-443.

Owens, R. L., & Higgins, K. E. (1979). The long-term stability of the dark focus of accommodation. American Journal of Optometry and Physiological Optics, 69, 646-652.

Simonelli, N. M. (1983). The dark focus of the human eye and its relationship to age and visual defect. Human Factors, 25(1), 85-92.

Westheimer, G. (1957). Accommodation measurements in empty visual fields. Journal of the Optical Society of America, 47, 714-718.

Whiteside, T. C. D. (1957). The problems of vision in flight at high altitude (AGARDograph No. 13). London: Butterworths Scientific Publications.

APPENDIX A
Laser Hazard Evaluation

REPLY TO
ATTN OF: Med Cen/SGPB   25 September 1984

SUBJECT: Laser Hazard Evaluation

1. TO: AMRL/SE (Lt Col Sanders)

1. On 12 September 1984, a Laser Hazards Evaluation and Survey was conducted
for the AMRL Human Engineering Branch, Building 248, Room 302 by Lt Speer
Department of Bioenvironmental Engineering. Jill Easterly was contacted and
assisted with the survey. Lt Speer also contacted John Henderson by phone to
discuss the laser.

2. The laser operating parameters and hazard evaluation are as follows:

Laser: Hughes 3203H-01 Serial Number 1060077
Type: Helium Neon, Continuous Wave
Power: 5 milliwatts
Beam Diameter: 0.05 centimeter
Beam Divergence: 1.7 milliradian
Safe Eye Exposure Distance (SEED): 14 meters for 10 second exposure
AF Category (CAT) C laser

3. This laser was a part of an instrument used to make optical measurements
on human subjects. The laser beam passed through a series of mirrors, prism
and neutral density filters before being displayed on a rotating white drum.
The diffuse reflection of the beam was projected through additional mirrors,
prism and beam splitter and then into the test subjects eye. The subjects
view this image for a few seconds to orient them and then view repeated pulses
of less than 1 second each.

4. The laser was evaluated according to requirements in AFOSH Standard
161-10, Laser Hazard Evaluation and found to be an AF CAT C laser. Because
the raw beam was contained entirely within the testing instrument and was not
exposed, the laser can be considered to be a AF CAT A laser system. The image
that the subjects actually saw was a diffuse reflection of the beam. The
diffuse reflection from the laser was evaluated and found to be eye safe at
any distance or exposure duration.

AFLC - Lifeline of the Aerospace Team

5. Recommendations:

    a. The laser must not be operated with any access covers removed that would expose the beam including the access for the neutral density filter.

    b. The laser must be reevaluated if any changes are made to the optical train or filters.

    c. Refer all servicing to the equipment manufacturer.

    d. Laser goggles are not required provided no covers are removed.

    e. Eye exams as specified in AFOSH Standard 161-10 are not required for operator or test subjects.

    f. If anyone experiences optical discomfort during operation of the devise, discontinue use and request emergency evaluation from Bioenvironmental Engineering.

6. If you have any questions, please contact Lt Speer at 53807.

WILEY TAYLOR, Major, USAF, BSC
Chairman, Dept of Bioenvironmental
Engineering

Cy to: AMRL/HEA

MEMORANDUM

TO: Maj. Arthur Ginsburg   DATE: 19 August 1982
                                          6630-M-82-8-1
FROM: Dr. William R. Mallory, SRL

SUBJECT: Laser Speckle Optometer Safety

The references herein are to figures, tables, and paragraph numbers in American National Standard for safe use of lasers, hereinafter referred to as ANSL.

1. The laser used in the SRL Laser Speckle Optometer is Class 3a. (ANSL. para. 3.3.3.1 and 3.3.3.2. Wavelength between 0.4 μm and 0.7 μm, and output power less than 5 mW.)

2. The only possible viewing of the laser radiation through the instrument is from a diffuse reflector. Therefore the standards for extended sources may be used for this diffuse source if its angular subtense, α, is greater than α_{min}. (ANSL para. B3.2.1. It is stated therein that, unless focused, no Class 3 lasers will produce hazardous diffuse reflections.)

From figure 3 of ANSL, for 1/4 sec viewing time α_{min} = 12 mrad. This viewing time produces the smallest α_{min} for any usage conditions. It can be shown by calculation using the properties and positions of the elements in the optical system that α = 0.43 rad., which is much greater than α_{min}.

3. As a further precaution, the flux incident on the eye was calculated and compared to the Maximum Permissible Exposure (MPE) shown in table 6 of ANSL. The worst case calculation gave 2×10^{-4} watt/(Cm² Sr.) for actual flux. To convert this number to energy, E, in Joules/(Cm² Sr.), it is only necessary to multiply by the exposure time. From ANSL, table 6, MPE for a laser of wavelength 632.8nm (0.6328 μm) (wavelength of the HeNe laser used in the optometer) for exposures between 10^{-9} and 10 sec is $10 t^{1/3}$ J/(Cm² Sr.).

For t = 1/4 sec, this yields 6.3 $J/(Cm^2$ Sr.) compared to (for 1/4 sec) E_{actual} = 0.5 X 10^{-4} $J/(Cm^2$ Sr.).

For other times,

t = 1/2 sec   E = 1 X 10^{-4} $J/(Cm^2$ Sr.)

t = 1 sec   E = 2 X 10^{-4} $J/(Cm^2$ Sr.)

For a continuous exposure (Assume 100 sec max. exposure)

Table 6 ANSL gives 21 $J/(Cm^2$ Sr.) allowed compared to

E = 2 X 10^{-2} $J/(Cm^2$ Sr.) actual

Conclusion: Exposures are far below safe limits.

Attachments

APPENDIX B

Informed Consent

INFORMED CONSENT

I, _____, give to Essex Corporation and the U.S. Air Force
Academy, my permission to participate as a subject investigating the development
of visual testing or screening of pilot-qualified USAFA cadets. I have been
given, and have read, an introduction to the study and information on the
apparatus, a laser optometer, and understand the purpose of the experiment. I
understand that the optometer has been man-tested for safety purposes through an
engineering study, and that exposure to the laser is indirect and less than one
second per trial. I am able to withdraw from the experiment at any time and my
participation in this experiment is entirely voluntary.

SIGNATURE_____ DATE _____

EXPERIMENTER SIGNATURE_____ DATE _____

END

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